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A CONTRIBUTION TO THE STUDY OF PUNCTATE BASOPHILIA IN LEAD WORKERS*

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EARLY in the year 1921 the writer was asked by Dr. T. M. Legge, H. M. Senior Medical Inspector of Factories, to take part in an investigation into the subject of punctate basophilia in lead workers. Observations commenced in 1921 have been continued up to the present time and a report is now in preparation.

One of the matters calling for special inquiry was the reliability of the methods in general use for the detection of punctate basophilia and the question whether they are suitable for employment on a large scale.

The chief aim of the writer in commencing the work now published was to obtain some evidence bearing on these matters, but opportunities occurred of collecting information on the main subject of punctate basophilia and lead poisoning. Some results are given in the following pages, though various details of technic are omitted and will be included in a forthcoming report.

The present contribution continues some observations published in 1914 and 1918 on the employees of an accumulator works. In January, 1921, the Chloride Electrical Storage Company consulted the Director of the Public Health Laboratory[1] concerning the possibility of training two of their chemists in methods of blood examination so that they might assist

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[1] Now Department of Bacteriology and Preventive Medicine, University of Manchester, under the directorship of Professor Topley.

Dr. MacMillan, the appointed surgeon, in the medical control of the employees. Professor Delépine, at that time Director of the Laboratory, decided that the proposal should be given a trial, and the writer was asked to arrange a special course of instruction. This course was given during the summer of 1921. It extended over a period of about two months' time with two meetings a week, each of about two hours' duration. The teaching was entirely practical and intended to make the pupils familiar with one simple routine method of preparing, staining, and examining blood films for punctate red cells and of estimating their number. They were equipped with a suitable microscope and everything necessary for their work at the chemical laboratory of the works. They became quite competent in about two months' time.

Their observations were controlled by means of duplicate films from each case sent to the writer. On comparing results many quantitative disagreements were found. Usually the pupils found more punctate red cells present in a given case than did the writer, probably on account of their superior diligence, but they never found punctate red cells when the writer found none and *vice versa*.

In the following tables the writer has made use of the pupils' results uncorrected in those instances where disagreements occurred. They are as reliable as the work of any competent observer trained in this special kind of microscopic work and as accurate as the nature of the work permits.

The clinical notes were collected by Dr. MacMillan and recorded on special case sheets. The records contain notes concerning the date of employment; previous occupation and illnesses; family history; height, weight, complexion; state of the mouth, teeth and gums, throat and nose; defects or injuries; digestion; heart, pulse, blood pressure; lungs; general habits (tobacco, alcohol, diet, exercise, cleanliness, home); occupation, change of occupation, and the necessary dates. The men were examined from time to time and full notes kept covering the period of the inquiry.

The Chloride Company manufactures electrical accumulators. About 500 employees are under the special regulations for lead workers. The works is situated in a wide, open valley in semirural surroundings and is divided into a number of separate sheds. The buildings are of modern construction. Much attention is given to the hygienic welfare of the men by providing canteens, recreation grounds, washing accommodation, overalls, fans, and various other apparatus. Apparently the employees stay longer than at most works where exposure to lead is inevitable, and their general physique and social standards are certainly higher than those of the average casual laborer.

The films were made on slides from blood obtained from the lobe of the ear. They were fixed in absolute alcohol (twenty minutes) or methyl alcohol (three minutes) and stained by the following method:

Methylene blue (med. pur.)....	1 gm.
Sodium bicarbonate.....	6 gm.
Distilled water.....	200 c.c.

Stain half a minute. Wash in water till the film becomes a pale greenish color. Dry with blotting paper. Examine without cover glass with a one-twelfth inch oil immersion lens.

The microscope was fitted with an Ehrlich's micrometer eyepiece and mechanical stage. One hundred fields were examined and the results are stated as the number of punctate red cells present per million red corpuscles.

TABLE 1

WORK	NUMBER OF MEN	MEAN AGE	NUMBER OF MEN WITH		PERCENTAGE OF MEN WITH POSITIVE FINDINGS
			Negative Findings	Positive Findings	
Forming	4	28	3	1	25
Casting A	11	25	8	3	27
Lead burning	2	28	1	1	50
Pasting	37	29	14	23	62
Casting B	24	21	7	17	70
Filling plates	4	30	1	3	75
Furnace	26	30	6	20	76
Plate stores	5	31	1	4	80
Totals	113	26	41	72	63.7

The time spent on each film varied from a few minutes to an hour. The writer cannot examine more than three films in an hour and cannot do more than four hours' work in one day. The work is laborious and trying to the eyes, owing to the fact that many punctate red cells contain excessively fine granules. Probably many discrepancies are caused by the occurrence of such finely granular forms, for they are very easily missed.

A complete survey of the blood condition of the whole group of lead workers was not possible. The cases selected for examination were those that appeared likely to yield information bearing on the subject of punctate basophilia generally. The men were not chosen necessarily because they showed some sign of illness, though many men were examined in order to assist Dr. MacMillan in making a diagnosis; the selection was practically of the nature of a random sampling. Some men were picked out because they were engaged in some particular kind of work, or were likely to remain at work long enough to enable a series of observations to be made, or on account of various other reasons too numerous to mention in detail.

During the period 1921 to 1924, inclusive, records of 427 films from 158 men were collected. The various tables given are drawn from these films but the whole records are not included. In some tables cases had to be excluded which were available for inclusion in other tables, owing to insufficient details of information or for other reasons.

Table 1 shows the incidence of punctate basophilia in the men engaged in various occupations or processes. Cases of definite lead poisoning are not included. The "work"

is work at the time of the first note on the case sheet. In many instances the men were employed at some period at more than one occupation or process either before or after the first note.

The results are taken from the findings of the first examination when more than one examination was recorded. Some cases at first negative subsequently became positive. The

TABLE 2

SHED NUMBER	WORK	NUMBER OF MEN	NUMBER OF MEN WITH		PERCENTAGE OF MEN WITH POSITIVE FINDINGS
			Negative Findings	Positive Findings	
14	Forming	4	3	1	25
3	Casting A	11	8	3	27
8	Assembling	2	1	1	50
1	Pasting	54	17	37	68
7	Casting B	24	7	17	70
2	Furnace	27	7	20	74
9	Filling plates	4	1	3	75
8	Plate stores	5	1	4	80
Totals		131	45	86	65

"Positive" means merely that punctate red cells were present. "Forming" is an electrical process involving little danger from exposure to lead. "Casting A" is a process of die casting. The molten metal is introduced mechanically by pressure into molds. The melting pots are enclosed. "Casting B" is practically the same as casting A, but the metal is poured into molds by hand ladles. "Lead burning" includes several kinds of work in which small articles are melted by an oxy-hydrogen flame. "Pasting" is loading plates by hand with a paste containing lead compounds. "Filling plates" is a process in which ribbons or coils of metallic lead are placed by hand into frames. The furnace is a blast smelting furnace for recovering lead from scrap materials. "Plate stores" work involves some exposure to lead in the form of dust.

table shows the results of a survey by random selection with one test only for each man.

There is a fairly definite relationship between the occurrence of punctate basophilia and the nature of the work. The occupations given might be arranged in the following order, beginning with the one involving practically no risk: forming, filling plates, lead burning, casting A, casting B, plate store, pasting, furnace. It is not possible to eliminate the disturbing influence of previous occupation and it is possible that the single positive case among the workers engaged in forming was really the result of other work. Probably also the occupation of casting appears to be more hazardous than it really is, and no account is taken of the effect of the duration of exposure to lead in each group, as sufficient numbers of

observations were not available. The furnace work involves a high degree of exposure to lead but the furnace is worked intermittently. It is usually run night and day for a time and then stopped entirely, the men being drafted to this work from other work as required. In spite of these disturbing factors it seems clear that the more dangerous jobs yield a larger percentage of positives; probably with a more extended series of observations it would be possible to arrive at some sort of standard for various occupations. If this could be accomplished, surveys of lead workers by means of blood examination would be of considerable value in the control of various industries.

In Table 2 the incidence of punctate basophilia according to various sheds is shown. In some sheds more than one kind of work is done. The term "work" means the chief work. A number of cases are included which are not contained in Table 1. Some of these cases were in laborers.

A laborer in a shed where a dangerous process is carried on is frequently exposed to the same risk as a man engaged in that process. Probably in many instances it would be advantageous for administrative purposes to estimate the incidence of punctate basophilia according to the shed or place of work rather than according to occupation.

TABLE 3

SHED NUMBER	WORK	NUMBER OF MEN	PERCENTAGE OF MEN WITH PLUS POSITIVE FINDINGS	MEAN OF HIGHEST COUNTS
	Joiners	3	0.0	.....
14	Forming	4	0.0	.....
5	Casting A	11	0.0	.....
8	Assembling	2	0.0	.....
7	Casting B	24	4.2	3,236
2	Furnace	27	5.0	4,737
4	Plate stores	5	6.0	5,375
9	Filling plates	4	7.5	3,333
1	Pasting	54	9.2	11,095

Table 3 includes a few cases of workers not exposed to lead which serve as controls. Plus positive means a high degree of punctate basophilia, that is, the presence of punctate red cells in comparatively large numbers, more than 1,000 per million. The last column shows the mean of the highest counts in instances where there were records of more than one count and is included merely to give some idea of the number of punctate red cells which may be found in various circumstances. In this table men working under lead conditions for short periods (less than a month) are excluded.

These results suggest that a better indication of the relative danger of

various occupations is obtained by a method of blood examination which involves a numerical estimate of the degree of punctate basophilia than by determining merely its absence or its presence. The results also suggest that standards ranging from 100 to 500 are too low. None of the men included in Table 3 showed definite signs of lead poisoning. Some cases included in Table 2 are not included in Table 3, and *vice versa*.

TABLE 4

CASE NUMBER	WORK	CHIEF SYMPTOMS	INTERVAL SINCE EXPOSURE TO LEAD	SYMPTOMS STILL PRESENT
			yrs./mos.	
27	Caster	Colic; constipation	3/–	Slight tremor
29	Caster	Colic; anemia	2/7	None
30	Caster	Colic; tremor	2/4	Slight anemia
32	Caster	Colic; wrist drop	1/9	Slight wrist drop; occasional colic
4	Laborer	Colic; constipation; tremor	–/8	Slight colic

In Table 4 are summarized some observations on men who had recovered more or less completely from plumbism. No punctate red cells were found in any of these cases.

In cases of plumbism punctate red cells may be found for a long period after exposure to lead has ceased. They may be absent when symptoms are present, or *vice versa*, and may disappear for a time and appear again. There is no constant correspondence between severity of symptoms and degree of punctate basophilia, nor between progressive diminution in the number of punctate red cells and progress toward recovery.

Table 5 shows the number of punctate red cells per million red cells found in eight men who were transferred to non-lead work without definite symptoms of lead poisoning but with some suspicious signs, and in three men with definite signs of lead poisoning. The third column gives the duration of exposure to lead at the time of transfer or cessation of work. The fourth column shows the number of punctate red cells found within a reasonable time after cessation of exposure to lead but not invariably on precisely the same date as the date of transfer or cessation of work. There is a high degree of punctate basophilia in ten instances. In the first case only one examination was made—three weeks after exposure to lead had ceased. In six cases more than 10,000 punctate red cells were present, and in four cases more than 20,000.

It is probable that a high degree of punctate basophilia is present in practically all cases of lead poisoning, provided that the examination is made within a week or two after exposure to lead has ceased; but there are exceptions, and a high degree is by no means a certain proof of lead poi-

soning. It may occur and persist for long periods without any sign whatever of ill health. It may appear within a few days of commencing work and show violent fluctuations from time to time; it usually vanishes slowly after exposure has ceased.

TABLE 5

CASE NUMBER	WORK	DURATION OF EXPOSURE TO LEAD	PUNCTATE RED CELLS PER MILLION RED CELLS
		yrs./mos.	
17	Casting.....	1/7	285
8	Filling plates....	3/7	2,000
150	Casting.....	4/11	3,000
152	Plate stores.....	–/7	3,400
88	Paster.....	1/6	5,700
108	Paster.....	3/6	23,500
118	Paster.....	9/–	25,000
105	Paster.....	8/6	26,000
33	Paster.....	7/–	14,400
2	Paster.....	3/7	15,000
60	Casting A.....	–/11	27,100
	Casting B.....		

Some of the peculiarities of punctate basophilia are illustrated in the following cases, where it was possible to collect records of several examinations at various intervals.

CASE 64.[2]—Worker in pasting shed, aged 21 years.

Date		*Punctate Red Cells*
Oct.	24, 1922	Began work.... None
Jan.	8, 1923	 3,410
April	25, 1923	 9,400
July	3, 1923	17,300
Oct.	29, 1923	12,700
Feb.	6, 1924	Good health. No sign of plumbism

CASE 34.[2]—Paster for seven years, aged 37.

Date		*Punctate Red Cells*
June	15, 1922	 1,080
Nov.	16, 1922	 5,120
Jan.	8, 1923	 3,500
April	19, 1923	 2,000
July	3, 1923	 8,100
Oct.	29, 1923	 8,800

CASE 97.[2]—Paster for three years, aged 26.

Date		*Punctate Red Cells*
Jan.	8, 1923	13,000
April	19, 1923	11,200
July	3, 1923	16,000

CASE 108.[2]—Paster for three and one-half years, aged 30.

Date		*Punctate Red Cells*
Jan.	8, 1923	11,400
April	19, 1923	 7,000
July	3, 1923	10,900
Oct.	29, 1923	23,500
Jan.	30, 1924	Transferred to non-lead work .....
Feb.	7, 1924	 900

CASE 26.[2]—Furnace and plate stores for six years, aged 45.

Date		*Punctate Red Cells*
March	22, 1922	 7,700
Feb.	2, 1923	13,700
Feb.	23, 1923	16,200
March	17, 1923	 6,800
Sept.	16, 1923	11,300
Sept.	23, 1923	19,600
Oct.	1, 1923	10,100
Oct.	9, 1923	15,000
Jan.	3, 1924	 6,640

CASE 33.[3]—Paster for seven years, aged 28. (Lead poisoning.)

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[2] These men showed no symptoms of plumbism.

[3] This man had some suspicious symptoms in 1916, 1919, and 1920.

Date	Punctate Red Cells
June 15, 1922	1,730
Nov. 8, 1922	Some extensor paralysis. Suspended. Plumbism
Nov. 9, 1922	14,400
Nov. 16, 1922	14,200
Nov. 23, 1922	9,300
Dec. 7, 1922	5,700
Dec. 21, 1922	8,000
Jan. 18, 1923	4,000
Feb. 16, 1923	6,600
March 28, 1923	3,000
June 21, 1923	1,100

CASE 2.—Paster for three years and seven months, aged 40. (Lead poisoning.)

Date	Punctate Red Cells
Nov. 9, 1921	4,570
Nov. 1, 1922	Colic, constipation. Plumbism
Nov. 2, 1922	15,000
Nov. 9, 1922	14,400
Nov. 23, 1922	10,000
Dec. 7, 1922	4,800
Dec. 21, 1922	8,000
Jan. 18, 1923	2,100
Feb. 16, 1923	500
March 28, 1923	200
June 21, 1923	None

Table 6 shows the relation between various physical conditions and punctate basophilia in a total number of 138 men having various occupations involving exposure to lead. The men are divided into two groups, "above mean" and "below mean," and the percentages of positive and of plus positive are calculated, plus positive being more than 1,000 punctate red cells per million red corpuscles.

For the purposes of this table artificial teeth which many of the men used are not counted as teeth. Very few men had good teeth. The blood pressure was estimated by means of the Tycos apparatus, and one observation only was made at the time of the first clinical examination on the case sheet. Defects and injuries include chiefly old wounds and nothing that obviously impaired the man's general health or suitability for employment. There

TABLE 6

PHYSICAL CONDITIONS	TOTAL MEN	PERCENTAGE OF MEN WITH	
		Positive Findings	Plus Positive Findings
Height (mean 66½ in.):			
Above mean	86	61.6	38.3
Below mean	52	67.3	38.4
Weight (mean 139½ lb.):			
Above mean	79	55.7	32.8
Below mean	59	74.5	45.7
Teeth (mean number 19):			
Above mean	84	58.3	36.9
Below mean	54	72.2	40.7
Blood pressure (mean 117):			
Above mean	68	69.1	42.6
Below mean	70	58.5	34.2
Defects and injuries:			
None	77	58.4	35.0
Some	61	70.4	42.6
Tobacco:			
None	23	34.7	30.4
Some	115	69.5	40.0
Alcohol:			
None	66	62.1	37.8
Some	72	65.3	39.4
Exercise:			
None	54	75.9	40.9
Some	84	55.9	26.9

were no cases of disease of the lungs and only one of heart disease (aortic regurgitation). A large number of the men took some sort of physical exercise—football, walking, bowling, swimming—and practically all were personally clean and had good homes. Digestion was good in all but a very few instances.

The number of the records is obviously too small for statistical purposes; nevertheless, the table gives some idea of the general physique and social status of the men. The main purpose in collecting the details of clinical examination was to ascertain, if possible, what is the best kind of man to employ in conditions involving exposure to lead. Judging by the results shown it seems that the best man—that is, the man most likely to maintain his health—is one of about average height and weight, who has good teeth, low blood pressure, and no defects or injuries, and who is a nonsmoker and more or less of an athlete.

Conclusions

1. The methods employed in detecting punctate basophilia are simple and capable of being applied on a large scale. The enumeration of the number of punctate cells present is subject to inaccuracies, some of which are not capable of complete elimination by technical skill and personal diligence.

2. The presence of punctate basophilia is an extremely delicate method of detecting lead absorption. A blood examination is of great value to the clinician. It will often bring to light cases of lead absorption where the signs usually relied on are nonexistent.

3. The degree of punctate basophilia determined by an estimation of the number of punctate red cells present affords an indication of the amount of absorption taking place. A blood film examination is frequently of great value as a warning or danger signal.

4. A blood film examination similar to the one described in the preceding pages cannot be relied on as a crucial test to distinguish between lead absorption and lead poisoning.

The following remarks are intended to express the writer's views regarding the value of a simple blood film examination performed solely for the purpose of detecting and estimating punctate basophilia:

The chief value of a blood film examination rests in the fact that it supplies an objective sign outside the control of the patient. It affords a piece of medical evidence which must be considered along with whatever evidence is available in making a diagnosis.

Punctate basophilia is probably present in practically all cases of lead poisoning, but it may be absent or present only intermittently. Therefore a negative result should not be regarded as conclusive, unless repeated examinations have been made within a reasonable time of cessation of work. In typical cases of lead colic, punctate basophilia is almost invariably present and a negative result in cases of that type is strong evidence against lead poisoning.

A slight degree of punctate basophilia should be regarded as practically a normal condition in men exposed to

lead and is, therefore, a piece of evidence of no diagnostic value. A high degree is of greater diagnostic value but it is by no means a definite proof of lead poisoning. The writer is not prepared to say what constitutes a high degree, though the standards of 300 per million are certainly too low.

5. Routine film examinations are of the greatest service when used as a sort of detective agent, but are of less value in the diagnosis of lead poisoning. It is possible that further researches will disclose some method of distinguishing between lead absorption and lead poisoning.

The writer desires to express his appreciation of Dr. MacMillan's careful and laborious work, of the public-spirited action of the Chloride Company and its staff, and also of the willing co-operation of the workmen.

THE PHOTOGRAPHY AND MEASUREMENT OF FINE PARTICLES*

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THE photography of fine particles is an art, the success of which depends almost entirely on the manner in which the investigator has dispersed and mounted his material. If this has been done correctly, particle photography becomes a comparatively simple matter; on the other hand, if the mount is faulty, then the greatest skill and the finest equipment will be of little avail. Every microscopist undertaking particle work recognizes this statement as axiomatic, consequently the greater part of his time is not consumed in experimenting with new methods of illumination, new lenses, etc., but, instead, is devoted to the development of better methods of dispersing and mounting. He will, also, realize the fact that practically no two substances can be treated exactly alike; that is, each subject requires a somewhat different method of attack.

PHOTOMICROSCOPY

Terminology

The terminology used in particle work is of prime importance; in order, therefore, to keep our ideas clear from the start, and to avoid confusion, a chart devised for pigment microscopy is inserted (see Fig. 1). The terms are general and apply to materials other than pigments and fillers.

The Individual Particle.—The term individual particle refers to those minute units of matter (of which the material is composed) whose size and shape depend only on the force of cohesion. Such particles cannot be subdivided without separating like molecules that are within the range of the cohesive attraction of one another.

The Ultimate Working Unit.—This may be an individual particle, or it may be any group of individual particles that are so firmly held together by forces of adhesion that they remain intact as a group during the duration of their commercial application. Such a group is called a *complex*.

Aggregates.—Any group of two or more particles is an aggregate. There are three forms of aggregation included in the chart, the flocculate being the most important.

Flocculate.—Flocculation occurs only where particles have been incorporated in a liquid medium. A flocculate is a group of particles held together by a force, apparently arising from surface tension, at the interface. This force of flocculation is relatively weak and not comparable with the force of adhesion that holds complexes together, consequently flocculates do

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not function as large individual particles, and cannot be classified under ultimate working units. Under slight continuously applied force flocculates are constantly breaking down and re-forming.

When the investigator has a correct conception of these terms, it becomes easier to develop satisfactory methods for showing under the microscope either the ultimate working units or any of the various states of aggregation that may exist.

Preparation of the Mount

As stated, the preparation of the mount is the really important factor involved in particle measurement. It is evident that first, in order to obtain satisfactory results, the individual particles must be detached and evenly distributed; that is, all states of aggregation must be eliminated with the exception of complexes (if complexes exist). Second, the particles must not be broken or ground during the process of dispersion. Third, all the various sizes of particles that exist in a sample must be present in their correct proportion. Fourth, there must be a sufficient number of particles present to give a true average. Fifth, the particles must lie in one plane and be free from motion.

The method of preparing particles in such a manner that these conditions are maintained is described by the author in a paper entitled, "A Photomicrographic Method for the Determination of Particle Size of Paint and Rubber Pigments."[1] Briefly, the method consists in rubbing the particles out into an exceedingly thin layer with turpentine on a microscope slide, evaporating the turpentine, and mounting in glycerin or any other suitable medium.

This method requires considerable practice before a deflocculated mount can be made. The following variation is considerably easier to acquire:[2]

> The most useful pigment [particle] dispersions are those that are built up like wedges—that is, the particle density (number of particles per unit area or volume) varies gradually from a thin edge to a thick one. . . . On a wedge mount any degree of density can be found for inspection. At the thin edge of the wedge perfect deflocculation usually exists, and such a spot can be used for photomicroscopy and particle measurement, if desired.
>
> Rub out [with a glass rod on a microscope slide] the pigment with redistilled turpentine until all visible lumps are broken up. Hold the rod firmly so that it does not twist in the hand, then, with a rotary motion in the plane of the slide, pass the rod from one end of the slide to the other and backward again. . . . Continue the rubbing until the turpentine is nearly, but not quite, evaporated. (If the rubbing is continued too long, bunching and streaking of the pigment occur.) Place on a hot plate and drive off the last trace of turpentine. . . . .

When the correct rotary motion[3] is acquired, and the mount is sufficiently moistened with turpentine, the result will be a series of parallel wedges (built up of particles) running across the slide, consequently this type of mount

[1] Jour. Franklin Inst., 1921, *192*, 637.

[2] Green, H.: The Microchemistry of White Pigments and Inerts as They Occur Mixed in Paints. Jour. Indust. and Engin. Chem., 1924, *16*, 677.

[3] This motion is slight and is made with the arm nearly rigid. The motion is made principally from the shoulder. The radius of rotation is about 2 or 3 mm.

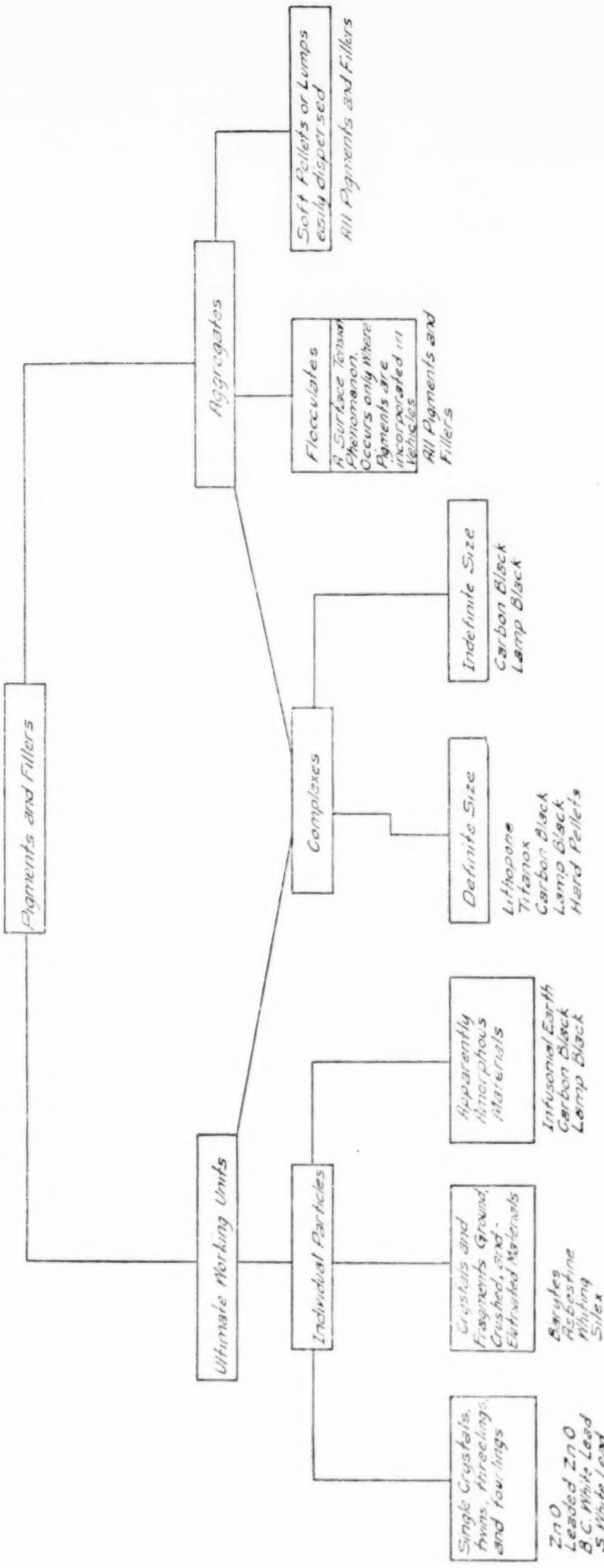

FIG. 1.—The relationships of terms used in pigment microscopy.

has been called the "multiple wedge dispersion." Such a mount is easy to make and is the most generally useful type; but it has one fault, and that is that it does not always give the highest state of deflocculation attainable. In order to produce complete deflocculation, resort must be had to a hot viscous mounting medium that will solidify on cooling. Melted dammar has been found useful in this respect and has been employed in making a type of mount called a "circular wedge dispersion." This has been described in the same paper from which the preceding quotation was taken.

Assuming that a suitable dispersion has been made by some method such as the multiple wedge type (but not the circular wedge), the next question to be settled is that of the proper index of refraction of the mounting medium. If the particles are so large that only low powers of the microscope are necessary, the material may be observed or photographed dry; that is, no mounting medium is used. If magnifications of 150 diameters and upward are required, it becomes imperative that the particles be fixed in a solid or liquid medium of some kind. If this material should have the same index of refraction as the particle, the particle becomes invisible if colorless; consequently in order to bring out the particle there must exist a difference in refractive index between it and the medium. Of course this difference exists when the particle is mounted dry, but as the index of refraction of air is much lower than that of glass, refraction of the light takes place with a resulting loss in numerical aperture; that is, the objective loses its ability to show fine detail correctly.

In order to obtain the full use of the aperture, the mounting medium should have an index of refraction not less than that of cedar oil (1.51). On account of the fact that the space between the cover glass and the slide in which the particles are mounted is very shallow, a slight departure from this rule is not serious. Glycerin, for instance, with an index of refraction of 1.47 makes a good medium for particles of high refraction, such as zinc oxide, basic lead sulphate, lithopone, etc.

If the particles have a low refractive index, the best medium is methylene iodide (1.76). The class of materials that gives the microscopist the most trouble is the one that falls between the approximate limits, 1.58 to 1.68. Glycerin is not low enough and methylene iodide is not high enough for such substances. If a dry lens can be used, water may be substituted for glycerin; but if high power is required, this procedure does not produce very satisfactory results—a condition due, as stated, to loss of aperture.

All textbooks on petrology and on microscopy give lists of media of high refractive indices, but these materials are composed mainly of antimony iodide, arsenic sulphide, antimony sulphide, sulphur, and selenium; consequently they are deep red in color and permit light of long wave lengths only to pass through them. The use of long wave lengths reduces the resolving power of an objective just the same as decreasing its numerical aperture; therefore these materials are not so satisfactory as microscopists

would like to have them. At present there are no entirely satisfactory media for materials of medium index of refraction.

Procedure

Assuming that we now have a mount ready for examination, the next step is the adjustment of the photomicrographic equipment. As the reader is presumably familiar with the various parts of such apparatus, they will not be described here.

Centering.—This means the alignment of all the optical parts so that their optic axes coincide throughout the system, from the illuminant to the eyepiece. The eyepiece is the starting point and is considered centered to begin with. It must be stated here that no photomicrographic system can be centered unless either the condenser or the objective holder (or both) possesses a centering device. If the condenser only has such an adjustment, then remove the nosepiece from the tube and screw into its place a 16-mm. objective. Next close the diaphragm under the condenser to its smallest possible aperture. Now turn on the illumination and rack the tube up or down until a sharp image of the diaphragm can be seen through the microscope (with eyepiece inserted, of course). Center this image with the centering screws on the condenser. Open the diaphragm and remove the eyepiece. Now look down the tube and center the illumination by moving the mirror. If this cannot be done, move the illumination slightly and then try centering again with the mirror. When the best possible centering is obtained by this preliminary method, put the object slide on the microscope and focus on it. Remove the eyepiece and again looking down the tube center the illumination by moving the mirror only, if possible. When the best possible adjustment is secured, place a small piece of ground glass on the top of the tube (eyepiece removed) and rack the condenser up or down until a sharp image of the illuminant is obtained on it. This is practically the position of critical illumination. If the image of the illuminant is not in the center of the opening of the tube, see if it can be put there by moving the mirror; if moving the mirror does not center the image, then move the source of illumination. If both of these procedures fail, return to the previous adjustment and center by means of the centering screws on the condenser. This adjustment must be only very slight, as the condenser should have been approximately centered.

The method of centering seems somewhat complicated, but it does not take more than a few minutes to go through the entire process after the investigator has become familiar with the apparatus. If the condenser does not contain a centering device and the objectives, instead, are provided with them, the process of centering is carried out in the same manner, except that adjustments are now made with the objective whereas they were previously made with the condenser.

When the microscope is equipped with both centering condenser and centering objectives, the problem becomes more complicated. The procedure in such a case is as follows:

Smoke one side of a microscope slide, and with a razor blade rule a fine cross on it. Mount in balsam and

wipe off the excess of carbon black outside the cover glass. Clamp this slide on the microscope stage and focus on it, using a 16-mm. objective and a medium power eyepiece. Next center the cross by moving the slide; remove the objective; loosen the tightening collar on the tube slide of the objective changer; rotate the tube slide through 180°; tighten the collar and insert the objective.

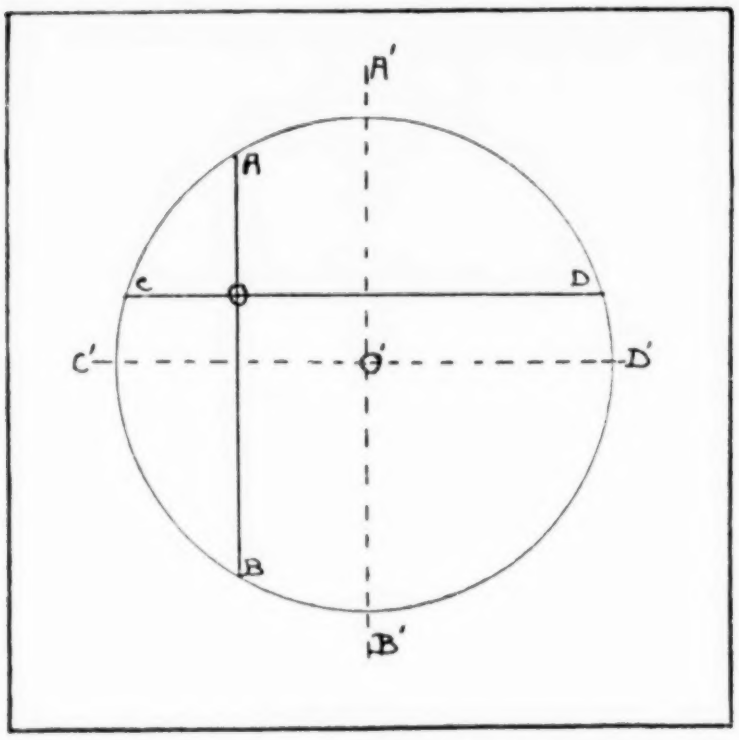

FIG. 2.—Showing the displacement of the cross from O′ to O when the objective is not in the center, and rotated 180°.

If the system happened to be correctly centered, a rotation through 180° would not cause a displacement of the cross. If displacement did take place, however, as shown in Figure 2, then turn the adjustment screw of the objective slide so that the line CD moves halfway to C′D′ (the central axis). Next move the mechanical stage until CD has moved the remaining half distance to C′D′. In the same manner move AB till it reaches the middle line A′B′. Now rotate again through 180° and if any small displacement is found to take place, center once more in halfway steps as just described.

The centering carried out thus far not only has centered the objective with the eyepiece, but also has placed the cross on the optic axis of the system. Remove the 16-mm. objective and replace with the 2-mm. objective. Center the cross with the adjustment screws of the objective slide only. Center the remaining objectives of the set in the same manner. The condenser and illumination are then centered as previously described.

The methods of centering given are for the vertical type of photomicrographic apparatus and objective changers similar to those made by Carl Zeiss. The vertical set-up has many advantages over the horizontal. For instance, it is less fatiguing to use, the camera can be swung to one side permitting the investigator to look into the microscope, the focuser need not be held in the hand (which usually shakes) but can be rested on the focusing screen, liquids do not run off the slide, the immersion oil is easier to put on, and the apparatus occupies less room and is usually cheaper.

Focusing.—The beginner is likely to assume that just as long as he has good eyesight and a properly illuminated object, correct focusing should be comparatively simple. As a matter of fact, it is easy to get large objects, under low power, in good focus without giving the subject much consideration; but fine particle work is an entirely different matter. If the particles to be photographed are very small, such as the finest zinc oxides and gas blacks, then monochromatic light must be used so as to

ture the condition that the chemical and visual foci are coincident. A difference of 0.25 micron would impair the results. This difference refers to the distance between the objective

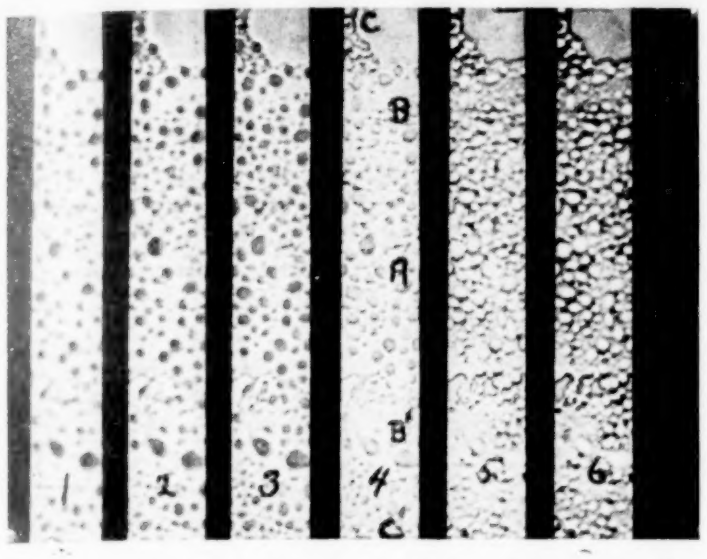

FIG. 3.—Series of strip photographs showing difference in shade of particles when passing from below to above the focus.

and the object, and not to the position of the focusing screen.

One of the important steps in learning to focus correctly is to make a thorough study of the appearance of the image both above and below the focus. Assuming that we are examining a colorless particle of higher index of refraction than that of the medium, then, starting above the focus and racking downward, it will be observed that the particle (except its edge) is whitish on a darker field and remains so until the focus has been passed, whereupon it appears dark on a lighter field. If the refractive index of the particle is lower than that of the medium, the transformations take place in the reverse order; hence focusing gives us a means of determining the relative positions of the indices of refraction of particle and medium. This test is more easily made if the condenser diaphragm is nearly closed.

A convenient method of studying the focus is by means of a sliding plate holder—taking a series of narrow photographs such as is shown in Figure 3. This series starts below the focus with exposure 1 and ends above with exposure 6. Each step in change of focus is 0.5 micron. The subject is a thin sheet of rubber latex particles mounted in water and taken at 1,500 diameters. It will be observed that the index of refraction of the particles is higher than that of the medium. Also it is apparent that exposure 4 is the nearest to the correct focus. At the center of the field, A, the particles are still slightly dark, and, since their index of refraction is above that of the medium, it follows that the lower focal plane of the eyepiece is slightly below the image formed by the objective. In other words, the objective is a little too close to the particles. At the extremities, CC′, the reverse con-

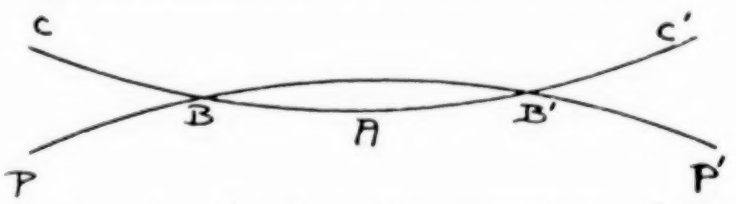

FIG. 4.—Showing the curvature of the focal and image planes of the eyepiece and objective. The points BB′ are in focus.

dition is true; therefore the correct focus is somewhere between A and C, at about the point B. This will be made clear on studying the diagram shown in Figure 4.

Figure 4 is a vertical cross section, showing the focal plane, CC′, of the eyepiece, and the plane of the image, PP′, formed by the objective. The point A is below the image; the points BB′ are exactly in focus; and the points CC′ are above the focus. To

bring the point A into the image plane of the objective, rack upward; to bring the points CC′ into focus, rack downward.

On account of the curvature of these planes it would be impossible to obtain a focus on more than a mere point in the middle of the field, or on a circle concentric to it, if the particles had zero depth. Since this is not the case—all particles having a finite depth—it becomes possible to have a field in focus considerably larger than otherwise, for in this case the cross section PP′ is not a line, but possesses a second dimension perpendicular to it and equal to the depth of the particle. Consequently in the outer zones, the tops of the particles will be in focus, while in the center of the field their bases will be focused. It follows, therefore, that the finer the particles, the smaller is the field they give that is in focus.

This natural curvature of the image and focal planes is usually considered a defect, but for fine particle microscopy it serves a useful purpose, giving the investigator a means of knowing not only on what side of the focus a photograph has been taken, but also indicating approximately how much the fine adjustment must be turned in order to secure a correct focus. Starting above the focus and racking down, stop at the point where the particles are about to change from white to black (or *vice versa*); this will be the correct focus. Make an exposure and examine the negative. If the point of change from black to white is not in the center of the field, the focus has been slightly passed.

On the other hand, if there is no indication that a change is about to occur—that is, the particles are all of one shade—then the focus has not been reached, or it has been passed completely; the particular shade of the particle will indicate which.

Making the Negative.—Assuming that we have a suitable mount, a centered system, critical illumination, and monochromatic light, the next step is to adjust the intensity of the illumination. Swing the camera to one side and focus on the particles. Open the diaphragm all the way and then gradually close it until the image is free from indistinctness due to too much light. If any of the standard photomicrographic illuminants are used, the field will still appear uncomfortably bright to the eye. When the eyepiece is removed, it will be found that the back lens of the objective is about two-thirds filled with light. Now swing the camera back in position and place in it a clear glass focusing screen. Rest upon the screen a focuser, just a trifle to one side of the center, and focus according to the instructions previously given.

For fine particle work a magnification of 1,200 to 1,500 diameters is desirable. This requires a 2-mm. objective, a medium power eyepiece, and an oil immersion condenser. When this combination is employed, together with medium speed plates, an exposure of five to ten seconds should be sufficient. For colorless particles less than 0.5 micron, it is desirable to use a contrast developer. Avoid developers that cause distortion of the gelatin. Print on glossy paper and finish on a ferrotype plate.

Determining the Particle Size

The term particle size should refer to the volume of the particle. It is customary, however, and more convenient to give it in terms of length, or diameter. The length of the diameter of a sphere, then, is its size; but what is the correct diameter to be chosen for nonspherical particles? This is the fundamental source of trouble involved in the direct measurement method, and a satisfactory solution for it will probably never be made.

It can be shown that

$$S \rho \mu = 6 \qquad (1)$$

where S is the surface in square meters of 1 gm. of material, ρ the density of the particle in grams, and μ the diameter of the particle in microns, all the particles being spheres of the same size. On account of the extreme simplicity of equation 1 it is desirable to apply it generally, and this can be done to a certain extent, for it is easily proved that the harmonic mean of the three dimensions of a rectangular parallelopiped also satisfies this equation. If we assume, therefore, that all nonspherical particles approximate in form a rectangular parallelopiped, the correct diameter to select will be the harmonic mean of its three dimensions. Photographically, only two dimensions can be shown, so the third must be estimated; this can be done in most cases with sufficient accuracy for general purposes. If the particles are small and roundish, the most practical procedure is to assume that they approximate spheres and to measure only one dimension.

Having decided on the most suitable diameter for the particle, the next problem is to determine the correct average particle size for a mass of material. The mathematical mean is used for calculating the uniformity coefficient, U, and for calculating the percentage of each size particle present, but it cannot be substituted for μ in equation 1, if we wish to determine specific surface. Perrott and Kinney[4] have recently shown that for specific surface determinations derived from equation 1,

$$\text{the correct average diameter} = \frac{\Sigma\, n\, d^3}{\Sigma\, n\, d^2} \qquad (2)$$

where d is the diameter of the particle, and n is the number of times it occurs, *i.e.*, its frequency.

Method of Measurement

After the negative is dry it is placed in a stereopticon and adjusted for a known magnification. The total magnification of the image thrown on the screen will be the magnification of the stereopticon times that of the negative. For fine particle work a total magnification of 25,000 diameters is usually sufficient. Mark the screen off into small squares and measure, with a millimeter rule, all the particles that are in focus in each square before proceeding to the next one. Do not skip any squares. The number of particles to be measured will depend on the degree of accuracy required and the uniformity of the material. With a substance like French Process zinc oxide, a fair average can be obtained from the measurement of a

[4] Perrott, G. St. J., and Kinney, S. P.: The Meaning and Microscopic Measurement of Average Particle Size. Jour. Am. Ceramic Soc., 1923, *6*, 417.

few hundred particles. On the other hand, materials of low uniformity might easily require the measurement of many thousands of particles.

As each particle is measured, it is called off by the investigator and marked down by an assistant. The time consumed per particle is somewhat less than a second. For a particle of the nonspherical type two dimensions are read and the third estimated. These are recorded on a separate sheet of paper, and their harmonic mean is calculated. This mean is then marked in its proper place with the spherical or approximately spherical particles. Particles that are decidedly tabular cannot have their third dimensions estimated very easily and are difficult subjects, therefore, for microscopic measurement. The scale on the fine adjustment can be used for measuring the depth, by focusing first on the top and then on the bottom of such particles. The difference in scale reading gives the thickness in microns. If the particles are acicular their depth is usually approximately equal to their width, and can, therefore, be estimated from the image on the negative.

In recording the measurements, the assistant should first mark down a vertical column of figures, commencing with zero and extending as far as is found necessary. These figures represent millimeters, and a stroke is placed after each particular one as a measurement is called out by the investigator. Systematized in this manner, it is an easy matter to calculate the mathematical average and the deviation of each size particle from the average (if the uniformity coefficient is desired).

$$\text{Uniformity coefficient, U, } = \sqrt{\frac{n}{2 \Sigma v^2}} \qquad (3)$$

In this equation, n is the number of particles measured and v is the deviation from the average.

If specific surface is required, the average diameter is calculated from equation 2, which necessitates the cubes and squares of the millimeter measurements. The result must be divided, of course, by the total magnification. If all the particles of a material are the same size, then $U = \infty$, and the uniformity is perfect. If $U = 0$, then no two of the particles are equal in diameter. The average diameter, together with the uniformity coefficient, completely defines a given material in regard to its particles. U is the so-called "precision" coefficient of the probability curve. Assuming that the particle frequency distribution gives that form of curve, then

$$n = k\, e^{-U^2 (x - a)^2} \qquad (4)$$

where n is the frequency of the particle size x, a the mathematical average, e the base of the natural logarithms, k the maximum value of n, and U the coefficient of uniformity. This equation is used to determine the percentage of particles of any given size occurring in a material.

The Measurement of Materials of Exceptionally Low Uniformity

Clays and ground products fall into this class. In spite of the fact that these materials are industrially important, it is doubtful if any very successful measurements have been made of them. Microscopically they are composed of some particles that are too coarse for high magnification and of

some that are too small for low; hence on a single negative all the particles cannot be in focus. If two exposures can be made of the same spot *and area*, one showing the coarse

FIG. 5.—A mount of zinc oxide correctly dispersed for photomicrographic measurements. × 1200.

particles in focus and the other the fine ones, a measurement can be made in the manner before described, provided enough particles can be photographed. This possibility is not likely to occur often; in case it does not occur, proceed as follows:

By elutriation, separate the material into three grades, (A) coarse, (B) medium, and (C) fine. Determine the percentages of A, B, and C, and call them X, Y, and Z, respectively. Take negatives of A, B, and C, measure the particles in each, and divide by their respective magnifications. Calculate the uniformity coefficients. Substitute these values in equation 4 and determine the percentage frequency of each size particle in the three groups. Multiply each frequency in A, by X; in B, by Y; in C, by Z. The result will give the frequency distribution curve of the original material and from this the average particle size can be calculated.

SUMMARY

In this paper it has been assumed that the reader is acquainted with the parts and uses of a photomicrographic outfit; consequently the author has dealt more specifically with the proper adjustment of equipment and the special technic for photomicrographic measurements.

The subject has been divided into two parts: the first dealing with photomicroscopy; and the second with the subject of particles and their measurement from the negative.

The various points that have been treated are: the terminology; the mount; centering the system and adjusting the illumination; focusing; making the negative; the size of the particle; the average particle size of a mass of material; the method of measurement; uniformity coefficient; and the methods for measuring materials of low uniformity.

THE LAUNDRY TRADE: III. ATMOSPHERIC CONDITIONS IN LAUNDRIES*

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NOBODY disputes the fact that it is necessary in the interests both of the workers and of the work that every factory should be comfortable, that the air should be pure and not stagnant, and that the temperature should be neither too high nor too low. The difficulty lies, as in the case of so many other problems, not with the aim but with the application of that aim.

What constitutes a good atmospheric condition? Nobody who has had experience of factories can have failed to meet the constant feud between fresh-air fiends and stuffiness-lovers; the atmospheric condition ideal to the one is loathed by the other. Fortunately, recent researches of Dr. Leonard Hill and others have enabled an objective criterion to be applied in place of the old subjective one. Dr. Hill has shown that concentration on the chemical properties of good air has obscured other equally necessary qualities, and that the thermometer is not a reliable indicator of atmospheric conditions. The bodily comfort and the efficiency of workers depend to a considerable extent on the cooling power of the air. Thus the temperature of two factories may be the same; if, however, the air of one is stagnant while that of the other is not, then the comfort of the workers in the two factories will be very different. The difference is best measured by the kata-thermometer which registers the cooling power of the air. This instrument registers the time taken for the thermometer to fall from 100°F. to 95°F. Details for the use of the instrument are given in various publications. It is not necessary for the understanding of the results obtained by the use of this instrument to study the actual theories underlying its use.

From very many observations Dr. Hill (1) estimates that the kata-thermometer should register a cooling power of 6 for sedentary workers. Little of the work of laundries can, however, be called sedentary, and much of it is heavy; a cooling power of 6 is, then, the very lowest that should appear in records of atmospheric conditions. In interpreting the following results the more a record exceeds 6, the better it is; the lower it is, the worse are the conditions.

Records were obtained from twenty-two laundries at the following posi-

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tions: at the hand-ironing tables, at the calenders, and at the packing tables. Some of the records were, however, taken during a heat wave and are therefore omitted from Table 1. Only those taken when the outside temperature lay between 47.5°F. and 67.8°F. are given. The extremes during the day are recorded. Consideration of this table shows that in only four cases was the desired standard of 6 approximated all day at the ironing tables, and that in no case was the standard maintained near the calenders. Practically speaking, it was only during the first hour of the morning that the standard was reached and in many cases not even then. None of the laundries could be described as representing the worst type of laundry; they are situated in different parts of England and range from the model factory built for a laundry to fairly good adaptations of buildings already in existence. It has to be remembered that in laundries the ventilation problem is complicated owing to the delicate nature of the work. When the wind is in certain quarters, or the day is misty, doors, windows, and ventilators generally have to be closed to prevent the intrusion of soot, etc., which, if it settles on a partially dry article, necessitates the rewashing of that article.

TABLE 1.—RECORDS OF THE TEMPERATURES AND THE COOLING POWERS IN FOURTEEN LAUNDRIES

LAUNDRY	MIDDAY OUTSIDE		HAND-IRONING TABLES		CALENDERS		PACKING TABLES	
	Temperature	Cooling Power	Temperature	Cooling Power	Temperature	Cooling Power	Temperature	Cooling Power
	°F.		°F.		°F.		°F.	
1	67.8	....	77–80	4.8–3.8	85–92	5.4–2.2	.....	.....
2	66.0	9.7	76–79	5.0–3.7	85–88	4.2–3.1	68–70	7.3–6.3
3	65.0	....	79–82	4.4–3.3	80–82	3.3–3.0	.....	.....
4	64.0	12.6	64–74	7.1–5.6	71–79	6.2–4.1	67–74	6.8–4.4
5	63.0	....	78–81	4.7–4.0	84–93	3.3–1.5	.....	.....
6	61.5	12.4	77–84	3.3–2.6	66–92	7.8–0.0	70–77	6.2–4.1
7	61.0	....	78–79	4.1–1.6	82–87	3.8–2.2	.....	.....
8	59.0	....	70–77	6.4–4.2	73–86	4.8–2.9	.....	.....
9	58.0	....	74–76	7.2–5.5	85–87	4.3–1.8	.....	.....
10	58.0	....	70–74	4.8–4.5	70–74	5.2–4.3	.....	.....
11	57.0	19.8	69–74	8.6–6.8	72–79	10.1–4.1	68–72	6.1–5.5
12	56.5	....	72–76	6.0–4.6	.....	.....	69–76	7.5–4.8
13	55.6	....	74–81	5.5–3.2	76–81	4.3-3.4	.....	.....
14	47.5	15.9	69–72	6.8–5.6	73–81	3.9–3.3	.....	.....

One laundry (Laundry A) which had been designed on modern lines and was equipped with fans of the latest model proved to have pockets of very stagnant air. The high temperature in a laundry is inevitable, but the stagnant character of the air is not. The manager of Laundry A, being interested in the problem, made various alterations which consisted of:

1. Lagging all steam pipes and under-surfaces of calenders.

2. Removing steam traps from the vicinity of calenders.

the changes were in progress, so that the records given do not represent the original conditions but a slight improvement on them, and again

TABLE 2.—RECORDS OF THE TEMPERATURES AND THE COOLING POWERS IN LAUNDRY A: AVERAGES OF OBSERVATIONS FROM 8 A.M. TO 6 P.M.

POSITION	COOLING POWER	RANGE OF TEMPERATURES	REMARKS
		°F.	
At a folding table			
Nov., 1921	5.86	68–76	This part is near a door and is only indirectly affected by steam-heated machines.
Nov., 1922	7.94	55.5–70	
At a calender			
Nov., 1921	3.40	80–85	Before any of the alterations, the cooling power could not be calculated although a fan was near. The 1921 records represent partial lagging.
Nov., 1922	5.90	71–78	
At an ironing table			
Nov., 1921	4.00	72–76	This part is near a door and windows, and is very much affected by the opening of the door.
Nov., 1922	5.70	72–73	
At the presses			
Nov., 1921	2.70	73–88	This part is affected not only by the heat from the presses but by the heat from the drying rooms which are nearby.
Nov., 1922	5.00	77–82	

3. Covering the lids of presses with asbestos.

4. Making additional ventilation gratings in the outside wall.

5. Substituting fine gauze panels for the doors so that air could be admitted but particles of soot, etc., excluded.

The comparisons of the cooling powers and the range of temperatures for this laundry, as shown in Table 2, are instructive. Readings were taken in November, 1921, when some of

in November, 1922, when all the foregoing alterations had been made. For purposes of comparison, two days have been selected when the outside temperatures were the same, *viz.*, 52°F. at noon, and the outside dry kata cooling power 16.2. It will be seen that the alteration resulted in considerable improvement.

If one compares records obtained every hour it will be seen that as the day wears on, the cooling power becomes less. The worker is, there-

fore, when getting naturally rather tired, working under conditions which are more uncomfortable than when she is fresh. It is not unreasonable to suppose that some of

TABLE 3.—HOURLY RECORDS OF THE TEMPERATURES AND THE COOLING POWERS IN LAUNDRY B ON TWO COOL DAYS IN MAY, 1922, AND ONE HOT DAY IN JUNE, 1922

TIME OF DAY	OUTSIDE		CALENDER		HAND-IRONING TABLE		PACKING	
	°F.	Cooling Power	°F.	Cooling Power	°F.	Cooling Power	°F.	Cooling Power
Average of Two Cool Days in May, 1922								
9.30	54.0	23.0	73.5	5.0	69.0	8.6	67.5	6.10
10.30	....	....	73.5	5.1	70.5	7.6	68.3	6.10
11.30	....	....	78.0	4.6	71.0	7.2	69.5	5.70
1.30	56.8	19.8	76.0	4.7	73.0	6.8	70.5	5.80
2.30	....	....	78.0	4.7	74.0	7.2	70.0	5.70
3.30	61.5	19.6	77.5	4.1	74.0	6.9	72.0	5.50
Hot Day in June, 1922								
9.30	74.0	8.4	83.5	3.7	....	...	82.0	2.90
10.30	....	....	....	...	92.0	2.2	85.0	2.20
11.30	....	....	85.0	2.5	93.0	1.4	89.0	2.10
1.30	81.0	6.0	87.0	1.6	95.0	...[1]	91.0	1.06
2.30	....	....	88.0	1.7	98.0	...[1]	91.0	1.30
3.30	78.0	8.7	85.5	2.1	97.0	...[1]	92.5	0.86

[1] In these positions the temperature was too high to enable the cooling power to be estimated.

the variations in output are not unconnected with the problem of ventilation. A system which may be quite adequate at the beginning of a day may be very inadequate at 3 P.M. Table 3 shows a comparison of hourly records for Laundry B. This was a one-storied building designed for a laundry and divided into two parts. The main building was ventilated by three impelling fans on the north side and three impelling fans on the south side. There was also a large exhaust fan in one gable. The records were taken on two cool days in May and one hot day in June, 1922.

Table 4 gives the comparative records of the cooling powers in laundries, potters' shops, boot and shoe factories, and weaving sheds. The readings were taken when the outside temperature was 50°F. or more. It will be seen that in the laundry trade 88 per cent. of the kata cooling power records were found to be below 6, as against 100 per cent. in cotton-weaving sheds, 89 per cent. in potters' shops, and 37 per cent. in boot and shoe factories; but in laundries 36 per cent. were below 3, as against 6 per cent. in potters' shops, 1 per cent. in cotton-weaving sheds, and 0 per cent. in boot and shoe factories. The air of laundries, therefore, may fairly be said to have a lower cooling rate than that of the other industries investigated.

From the point of view of the amount of air space for each worker, it is practically impossible to overcrowd a laundry, as the size of the machines is so great compared with the number of people who work them; but when machines which, from the nature of their work, must be at a very high temperature, are placed in an ill-ventilated room, it is to be expected that the air will become overheated and hence have a low cooling power. The hand-ironing department is, in most laundries, a

more comfortable place than the calender room. The problem for the launderer is to reduce the temperature in regions dominated by calenders and presses; even where a high temperature is necessary the condition can be mitigated by keeping the air moving.[1]

[1] The use of small fans, which merely keep the air in motion and which can be easily fixed without structural alteration, has proved beneficial in some places.

TABLE 4.—COMPARATIVE RECORDS OF THE COOLING POWERS IN LAUNDRIES, POTTERS' SHOPS, BOOT AND SHOE FACTORIES, AND COTTON-WEAVING SHEDS: READINGS TAKEN WITH THE OUTSIDE TEMPERATURE AT 50°F. OR MORE

COOLING POWER	PERCENTAGE FREQUENCIES							
	Laundries		Potters' Shops (2)		Boot and Shoe Factories (3)		Cotton-Weaving Sheds (4)	
Below 2.0	19	88% below 6	0	89% below 6	0	37% below 6	0	100% below 6
2.0–2.9	17		6		0		1	
3.0–3.9	21		23		8		31	
4.0–4.9	19		34		10		52	
5.0–5.9	12		26		19		16	
6.0–6.9	7		8		28		0	
7.0–7.9	4		2		20		0	
8.0–8.9	0.7		1		9		0	
9.0 or more	0.3		0		6		0	
Total observations.....	300		413		276		163	

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THE MANUFACTURE OF TIN PLATES: A COMPARISON OF OLD AND NEW TINNING PROCESSES*

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A NEW device, the Thomas and Davies machine, has been introduced in Great Britain for reducing the amount of labor required in the tinning processes of the manufacture of tin plates. We are not concerned with the technical advantages of the machine, but with contrasting the conditions of work of those employed when working at the usual process and at the new, and with the results as measured by lost time.

I. THE OLD METHOD

In the old process annealed plates are placed by hand into a cradle in which they are immersed first in an acid pickling bath (white pickling) and then in a water bath. Next the washed and wet plates are lifted out by hand and transferred to the tin-house where they are again lifted and placed into a water bath or tank beside the tinman. He lifts them in batches of fifteen to fifty at a time and deposits them on a slab at his side. A tinman produces fifty to sixty boxes of tin plate per shift, *i.e.*, he deals with 60 to 70 cwt. of dry plates; but when wet they weigh about 20 per cent. more than when dry. Hence he has to lift nearly 4 tons per shift in transferring the plates from the tank to the slab. He has next to lift the plates individually and thrust them one by one through a zinc chloride flux into a hot bath of molten tin. Although some water has drained off while the plates are on the slab, the weight lifted per shift probably still amounts to about $3\frac{1}{2}$ tons. The plates are moved on mechanically through the hot tin bath to a cooler tin bath with palm oil on its surface. In the old days a boy, or "riser," took each plate as it rose through rollers from the palm oil and transferred it to a dusting machine whence it was conveyed to polishing rollers; but in recent years the "riser" has been eliminated and the plates are passed on automatically to the dusting and polishing processes. After polishing, the plate is finished and ready for assorting and packing.

Various forms of tin baths have been devised but that known as the Abercarn pot (see Fig. 1) is the one in most

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general use in Great Britain. This pot consists of two baths of molten tin, the first (*i.e.*, the tin pot) being partitioned slightly below the surface of the molten tin so as to separate the zinc chloride (which is used as flux at the inlet end) from the palm oil that covers the other parts of the molten tin in the first and second baths. The pot is about 4 feet wide and 7 feet from front to back. The tin in the first trough, before which the tinman stands, is kept at a considerably higher temperature than that at which tin melts (233°C. or 451°F.). The tin in the second trough is only slightly above this temperature; if it gets too hot, the palm oil on its surface bursts into flame, but apart from this the heated palm oil gives off fumes containing acrolein and other irritating substances.

Dust rises into the air of the tinhouse as the plates pass through the pink meal used in the dusting process and through the polishing rollers. Owing to the constant production of fumes from the palm oil and of the dust just mentioned, the atmosphere of a tinhouse is always thick, and the windows speedily get coated with a thick layer of greasy dirt which is seldom removed. In our experience almost all tinhouses are in a state of semi-darkness, even when there is bright daylight outside. Tinmen almost always have to work by artificial light.

Notwithstanding much time and attention devoted to the subject by the industry and by the inspectors of factories,[1] no efficient means have ever been devised for removing from the atmosphere in which the tinman works the fumes and dust generated.

II. The New Method

The new method, called, after the factory where it was first installed, the "Melingriffith" machine, deals with the plates from the time they are annealed until they are ready for the assorting room. (See Figs. 2 and 3.) Annealed plates, conveyed dry into the tinhouse, are placed by boys in heaps on the receiving shelf of the machine. Thence they are picked up mechanically one by one and carried through the process of white pickling and washing, through zinc chloride flux into a hot tin bath, on to a cooler bath, out through a palm oil cover, and so to dusting boxes and polishing rollers, whence they are discharged on to a heap ready for packing. All handling, except that required to rectify a plate which chances to go astray or buckle in its progress, is eliminated from the moment the plates are placed on the receiving shelf.

A Melingriffith machine holds two to three times as much tin as an Abercarn pot, and the bath is correspondingly larger. More plates are passing through, and an operator at one of these machines has from three to four times as many under his supervision as a tinman working an Abercarn pot. There is more chance of the plates going astray and requiring to be put straight, as the operator has not so good an opportunity of rectifying irregularities before they begin to

[1] Collis, E. L., and Hilditch, J.: Report on the Conditions of Employment in the Manufacture of Tinplates, with Special Reference to the Process of Tinning. Cd. 6394. H. M. Stationery Office, 1912.

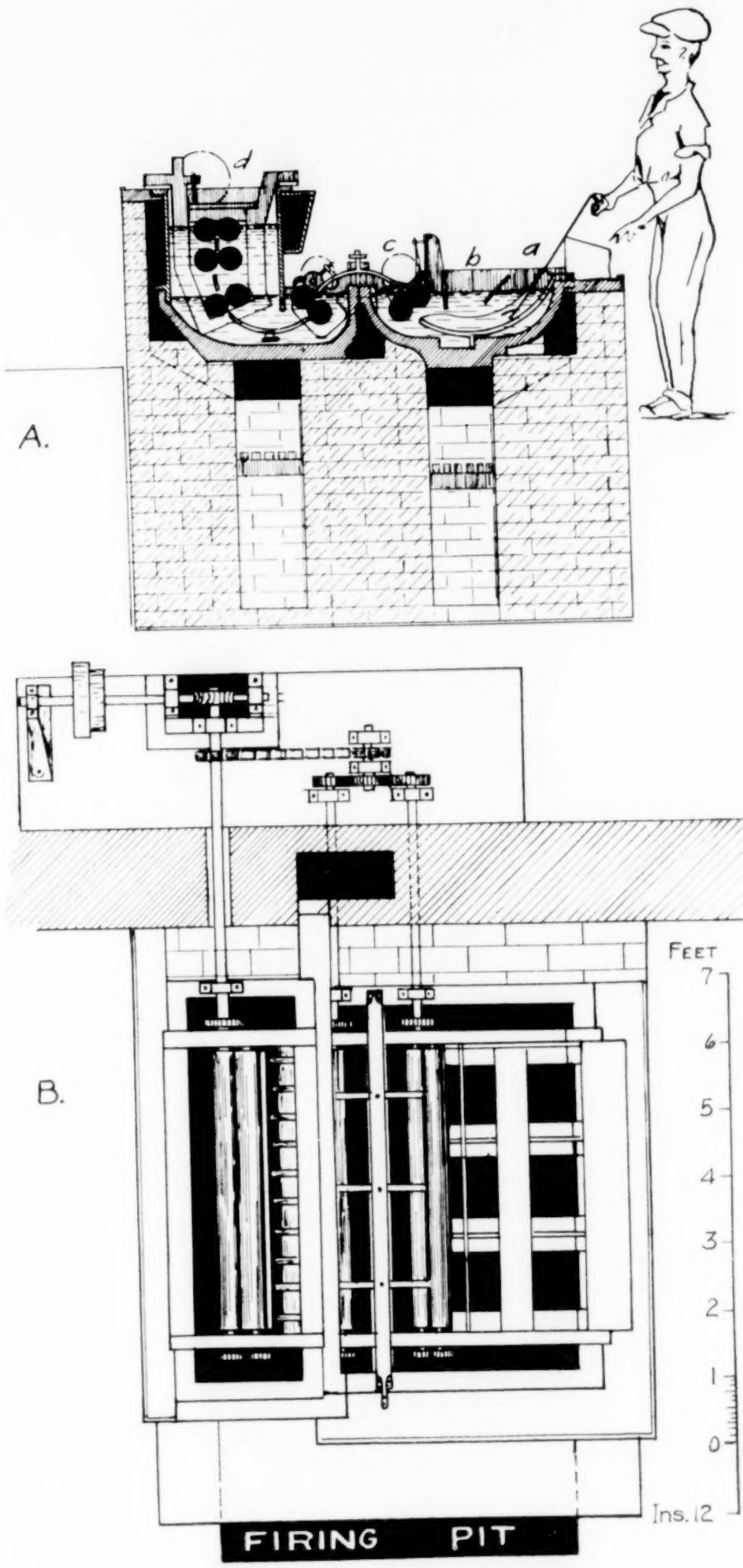

FIG. 1.—Abercarn pot.

A. In cross section. (a) and (b) indicate the hot tin bath with zinc chloride flux on the surface. (c) indicates the rollers guiding the metal plate out of the hot tin bath over through another pair of rollers into a cool tin bath or soaking pit. (d) indicates the place where the plate, after passing through other rollers immersed in palm oil, finally emerges.

B. Seen from above.

develop. Over the top of the tin bath is a gangway, along which the operator walks in order to attend to the machine from time to time and rectify plates. Above the whole machine, except the dusting and polishing portion, is a hood, 18 feet by 13 feet in size, from which passes a 6-foot ventilating duct, fitted with a volume fan revolving 400 to 450 times per minute. This creates a tremendous draft which draws away all steam from the acid bath, fumes and smoke from the flux and hot oil, and some of the dust from the cleaning apparatus. Hence the air of the workplace is kept free from smoke and nearly free from dust, in great contrast to the air where Abercarn pots are being worked. Moreover, there is no reason why the windows should not be kept reasonably clean and the operator be able to carry on his work (in so far as he is employed on a day shift) in good daylight.

III. Observations of the Investigation

A number of direct comparisons of the working conditions under both methods have been made by one of us (H. M. V.) at a tin-plate works where there were three Abercarn pots and three Melingriffith machines running in adjoining workshops. The investigator went backwards and forwards from one shop to the other in order to make comparisons, so that the effects of any changes in outdoor temperature and wind velocity were the same for both. The observations were purposely made during rather hot weather, when the conditions were likely to be most trying to the workers.

Most of the observations made relate to temperature and ventilation. The velocity of the air currents was estimated by means of the kata-thermometer, which was clamped to a rod screwed into the head of a telescopic tripod stand. The same stand supported a hygrometer, both instruments being fixed about 5 feet above floor level, and as near as possible to the actual working place of the operator. Direct velocity observations were made in addition by means of a metal vane anemometer, while quick temperature observations were made by an Edney sling hygrometer. This instrument is revolved at a rate of about 250 revolutions per minute, and it takes up the air temperature in $1\frac{1}{2}$ minutes. Though wet bulb temperatures were taken in every case, they are not referred to in this report, as they did not appear to yield any useful information.

Temperature and Ventilation at Abercarn Pots.—The tinman at an Abercarn pot stands close to the hot tin bath, so that he receives a large amount of radiant heat from it. There is no exact means of measuring the extent of this radiant heat, but the kata-thermometer observations made give some indication of it. The kata and the hygrometer had to be fixed near one end of the place where the tinman stood, and not at the middle, so that they should not interfere with his work. Hence the observations to be described rather underestimate the temperature. These observations were made under two sets of conditions: (*a*) when the bulbs of the kata and the hygrometer were fully exposed to the radiant heat from the bath, and (*b*) when they were protected from the radiant heat by holding a newspaper (folded once) about a foot away from

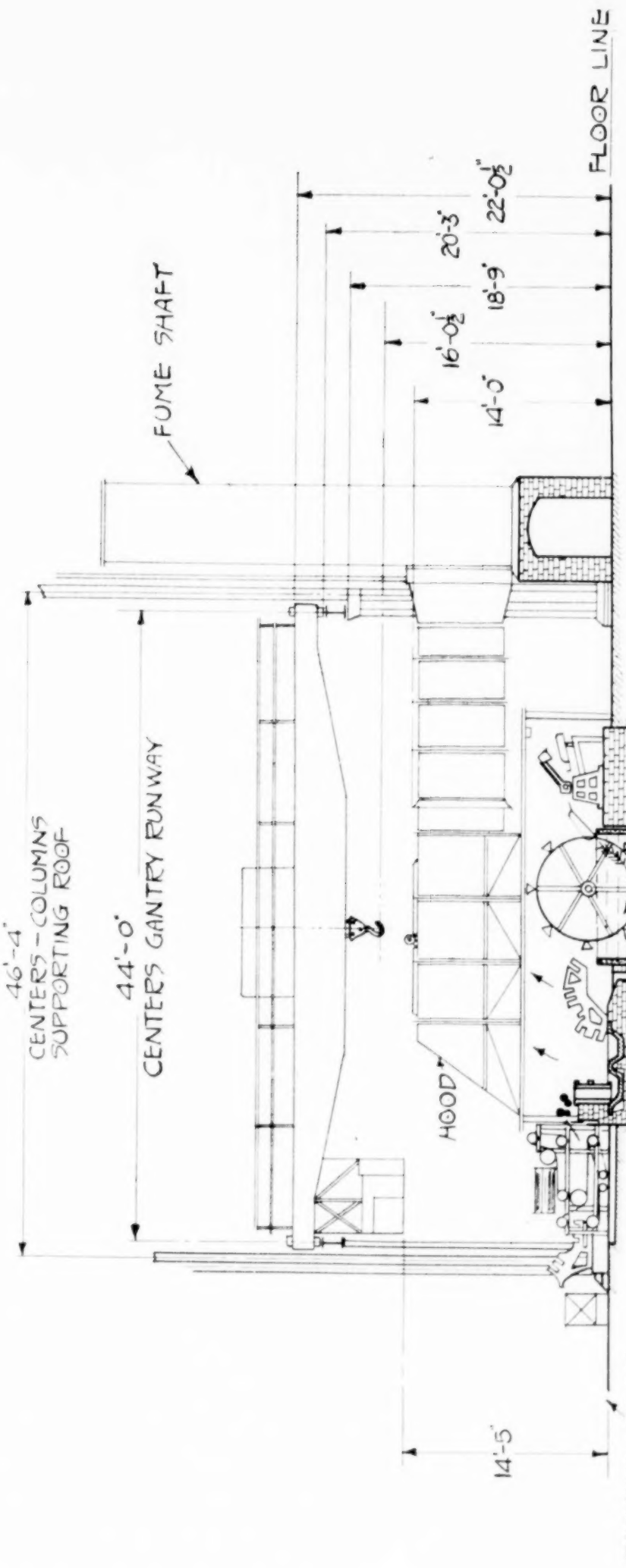

Fig. 2.—Sectional elevation of Melingriffith machine (9'-8" pickle tank fitted). Arranged between 46'-4" column centers.

the instruments, and between them and the bath. Duplicate observations of this character were made on three days at each of the three Abercarn mean of the direct observations, *viz.*, 111 feet, which were made at the same time by means of the metal vane anemometer.

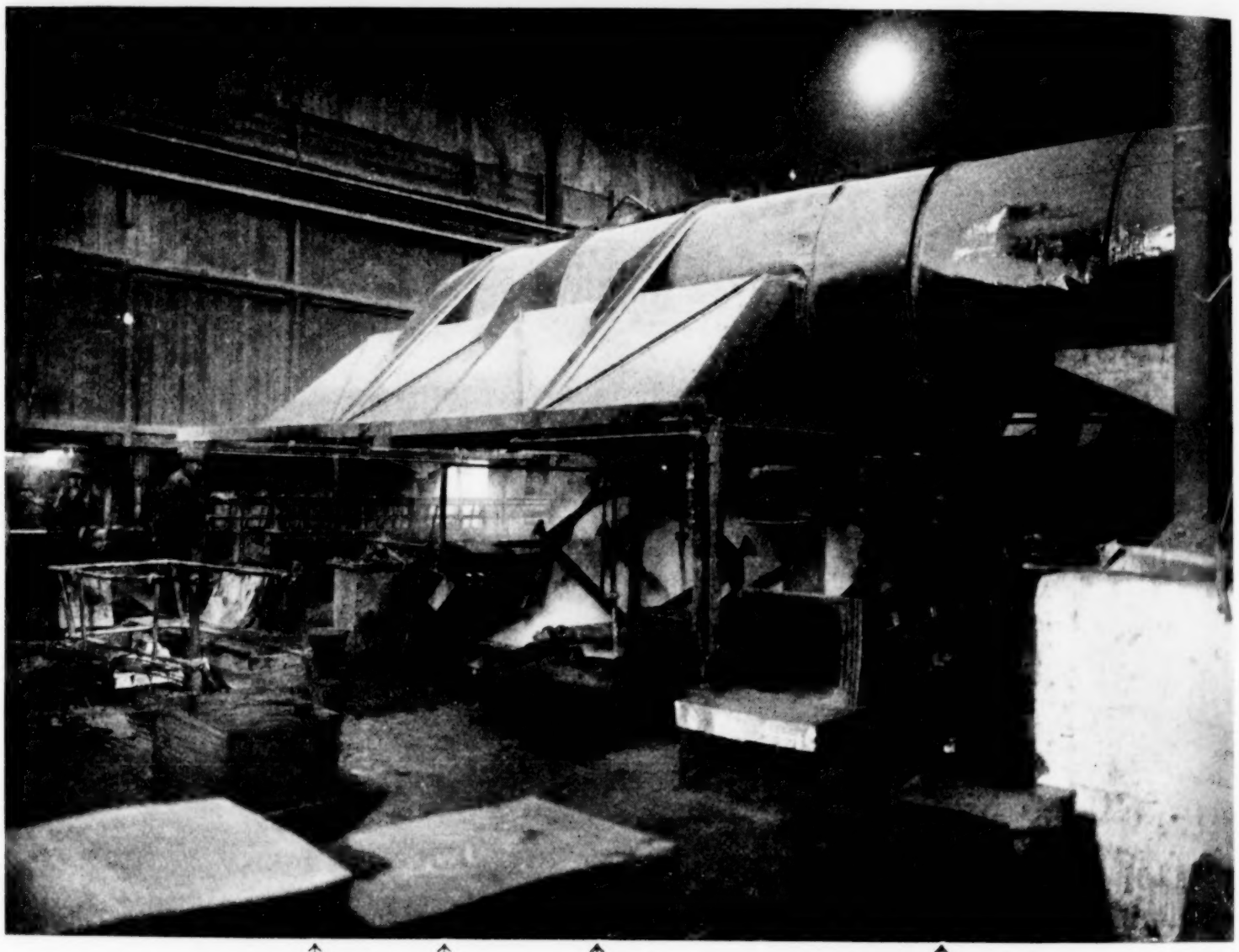

FIG. 3.—Melingriffith machine in operation.

pots, and the means of these observations are recorded in Table 1.

The mean dry bulb temperature recorded when the thermometer was exposed to radiant heat was 87.3°F., or 8.7° higher than when it was protected; while the cooling power of the air as registered by the kata was 2.5 as against 5.1. These temperatures and cooling powers indicate air velocities of 55 feet and 96 feet per minute, respectively. The latter value should be accepted as the correct one, and it corresponds roughly with the

As far as we are aware, the influence of radiant heat on the cooling power of the kata-thermometer has not hitherto been investigated, though it is sometimes a matter of great practical importance. In previous kata investigations our method has been to protect the instrument as much as possible from direct radiant heat (*e.g.*, of the sun, or of a furnace); but it is of interest in the present instance to determine its rate of cooling both when protected and when unprotected. There is no available information to show how the

rate of absorption of radiant heat by the human skin compares with that of thermometer bulbs, though perhaps it is somewhat smaller, as a glass surface absorbs heat very well.

TABLE 1.—EFFECTS OF RADIANT HEAT ON TEMPERATURE AND COOLING POWER (ABERCARN POT)

POSITION	PROTECTED FROM RADIANT HEAT			NOT PROTECTED FROM RADIANT HEAT		
	Temperature	Cooling Power	Air Velocity	Temperature	Cooling Power	Air Velocity
	°F.		ft. per min.	°F.		ft. per min.
Pot A.....	75.5	5.8	89	84.5	3.5	88
Pot B.....	81.9	3.8	65	90.5	1.5	32
Pot C.....	78.4	5.7	135	86.8	2.4	45
Mean.....	78.6	5.1	96	87.3	2.5	55

Opposed to the warming effect of the radiant heat, we have the cooling effect of the relatively cooler air currents which are impinging on the bulbs of the instruments, and which tend more and more to neutralize the radiant heat effect the greater their velocity. Hence, when the instruments are exposed to radiant heat, the conditions are very different from those observed in its absence, and do not yield data from which air velocities can be calculated by the ordinary formulae. At the same time, the fact that the cooling power of the kata was reduced by the radiant heat from 5.1 to 2.5, suggests that this heat made the conditions under which the tinmen had to work exceedingly trying; but until a number of further observations have been made under various experimental conditions, it is impossible to decide exactly what such a reduction of cooling power implies.

In making kata observations in the presence of radiant heat, the bulbs, both of the thermometer and of the kata, should be *either* fully protected from the radiant heat *or* fully exposed to it. In the ordinary hygrometer, the framework usually protects the bulbs to some extent, unless the instrument is kept facing the source of radiant heat, while the kata bulb is fully exposed. The results obtained under such conditions are hopelessly at variance (*e.g.*, H/θ values as low as 0.17 were obtained in the present investigation).

The temperature and the air velocity varied considerably at the different pots, as can be seen from Table 1. This was due chiefly to the habits of the workmen concerned. At pot B, where the air current was least and the temperature greatest, the windows close to the pot were almost completely blocked up by sheets of tin plate. The tinmen working there explained that they did not like a draft, and they did not remove the tin plates even on the hottest days. At the other two pots there was a certain amount of window ventilation, which lowered the temperature several degrees. The somewhat considerable air velocity observed at all of the pots was due to the presence of a wide and lofty chimney over each pot, to carry away the smoke arising from the heated palm oil of the tin bath.

At the time the observations recorded in Table 1 were made, the outdoor temperature averaged 64°F.,

but other observations were made in hotter weather. The temperature was taken at the actual spot where the tinman stood by means of the sling hygrometer, which was revolved at such an angle as to avoid any warming by radiant heat. At outdoor temperatures of 68°, 73°, and 79° it showed an average temperature of 81°, 84°, and 89° at the three pots—*i.e.*, an excess of 13°, 11°, and 10°, respectively. On the hypothesis that the radiant heat induced a further rise of 9°, it would follow that the effective temperature to which the tinmen were exposed ranged from 90° to 98°.

Temperature and Ventilation at Melingriffith Machines.—With the Melingriffith machine the operator of the machine does not have to stand near the hot bath. He usually stands at the side of the machine, and his head is nearly 6 feet from the nearest end of the bath (which is about 12 feet in length), as against 3 feet in the Abercarn pot.

Two or more sets of observations were made on each machine at the place where the operator usually took up his stand, and the means of the results obtained are recorded in Table 2. On an average, a temperature of 78.3° was observed when the instruments were protected from radiant heat, and one of 81.0°, or 2.7° more, when they were exposed to it. That is to say, the apparent radiant heat effect was not a third as great as that observed with the Abercarn pot. This was owing chiefly to the greater distance of the tin bath from the operator, but the considerably greater velocity of the air currents (produced by exhaust draft) impinging on the bulbs of the instruments must likewise have been partly responsible. The mean velocity observed was 156 feet per minute when the instruments were protected, or 1.6 times that observed with the Abercarn pot. The unprotected instruments, however, instead of indicating a smaller velocity than the protected ones, as they did in the observations at the Abercarn pots, showed a considerably larger one. This lack of correspondence may have been due in part to the obstructive action of the newspaper (used for protection) on the air currents; but it was likewise due to the differences in the conflicting factors of radiation and air cooling. In any case, a comparison of the data for the Abercarn pot on the one hand and the data for the Melingriffith machine on the other does undoubtedly indicate how much more favorable are the working conditions in the latter instance. Owing to diminished radiation and to

TABLE 2.—EFFECTS OF RADIANT HEAT ON TEMPERATURE AND COOLING POWER (MELINGRIFFITH MACHINE)

POSITION	PROTECTED FROM RADIANT HEAT			NOT PROTECTED FROM RADIANT HEAT		
	Temperature	Cooling Power	Air Velocity	Temperature	Cooling Power	Air Velocity
	°F.		ft. per min.	°F.		ft. per min.
Machine A.....	78.5	5.7	141	81.4	5.4	195
Machine B.....	82.4	4.5	128	84.6	4.4	197
Machine C.....	74.0	8.0	199	77.1	7.5	245
Mean.....	78.3	6.1	156	81.0	5.8	212

increased air velocity, the cooling power of the air near the Melingriffith machines kept at about 6, as against values of 1.5 to 3.5 observed with Abercarn pots.

The air temperature shown by the protected thermometer varied from 74° to 82° at the three machines. The differences were due to the fact that one machine was near to two doors, one or both of which were kept open. The outdoor temperature at the time these observations were made averaged 66°. Other observations, made with the sling hygrometer, gave a mean temperature of 76° at the operator's usual position when the outdoor temperature was 72°. Hence, the usual temperature conditions experienced by the operator were much less trying than those of the tinman on the Abercarn pot; but what conditions did he experience when on the gangway over the tin bath? Data recorded in a subsequent section show that he went about eleven times per hour on the gangway, for periods aggregating eight minutes. Five sets of observations were made at head level, (*a*) in the middle of the gangway, (*b*) halfway between the middle and the side, and (*c*) at the usual position of the operator, outside the gangway. At (*a*) the temperature varied from 98° to 112°, and averaged 106°; at (*b*) it averaged 86°; and at (*c*), 76°. Hence only for the short times that the operator was near the middle of the gangway (which could not have amounted to more than two or three minutes per hour) was the temperature experienced very excessive. Owing to the suction of the fan, the air velocities were considerable. They were measured by the metal vane anemometer, and were found to average 346 feet per minute at (*a*), 191 feet at (*b*), and 161 feet at (*c*).

Observations on the Player Pot.—In addition to the observations on Abercarn pots and Melingriffith machines, a few were made at another works on the "Player pot." The bath of this pot does not extend so far back as that of the Abercarn pot, but the farther portion of it is a good deal higher. The radiant heat from it, however, is probably not so great, the few observations made showing a difference of 4° to 5° between the protected and the unprotected thermometer.

Conditions Experienced When Stoking the Furnaces.—The tinman on the Abercarn pot has to stoke his furnace about four times during each eight-hour shift, and this takes him only about two minutes on each occasion. He stands in a small pit, but his head and body are above floor level; therefore the temperature conditions experienced are not at all trying. It is quite otherwise with the operator of the Melingriffith machine. His stokehole is completely underground, and he has two large furnaces to stoke. He has to remove the ash and clinker from each of them during his shift. This operation was said to take about ten minutes for each furnace, but the actual times observed averaged seven minutes. In addition, he stokes about four times more per shift for two minutes at a time, so that altogether he spends over twenty minutes per shift in his stokehole. Temperature observations were made in six stokeholes—three of them at another works than that above referred to. At a distance of 3 feet from the furnaces,

the air temperature averaged 97° (outdoor temperature being 66°). These observations were made with the sling hygrometer, revolved at such an angle as to catch no radiant heat from the furnaces. The doors of the furnaces were closed, except for small cracks; but when they were opened, as they had to be for stoking and clinker removal, the radiation was very intense. Any attempt to measure it was impracticable, as it would have broken the thermometers.

When an operator removed clinker, he took off the waistcoat which he generally wore previous to descending the stokehole, and he subsequently came up bathed in sweat, but he usually put on his waistcoat again in order to avoid getting chilled. The stoking for these machines was evidently very hot and exhausting work. Each stokehole had a ventilation opening, about 2 feet square, which in some cases led to a shaft opening outside the workshop. Also it had a large grating above opening on to the workshop. However, the velocity of the air currents in the stokeholes at the place where the operator stood when stoking was never sufficient to move a metal vane anemometer at all. In the light of control observations, this showed that the air velocity was less than 60 feet per minute—*i.e.*, it was very much less than that experienced by the operator when above ground, and a good deal less than that experienced by the tinmen when working Abercarn pots.

There can be no doubt that the ventilation could be greatly improved, for it differed a great deal even in the stokeholes of the various machines. For instance, the temperature of the best ventilated stokehole at one works averaged 86°, that of another 88°, and that of the worst ventilated one 110°. At the other works the temperatures of the stokeholes would have been still higher but for the fact that the furnace doors were covered with additional doors lined with asbestos. As it was, the stokeholes reached a distinctly higher average temperature than those at the first works, and the conditions were particularly trying in one stokehole which served the furnaces of two adjacent machines. The opposing furnace doors were only 8 feet apart, so that the stoker was exposed to heat both at his back and his front, wherever he stood.

Attention is already being directed to this matter, and in new layouts the spreading of the machines farther apart is advocated, so as to give much more room and better conditions for the stokeholes. Possibly artificial ventilation might be introduced, either by means of a separate fan or by bringing a branch duct from the huge 6-foot duct attached to the hood of the machine. The ventilation of the hood is so powerful that a small fraction could easily be spared for the stokehole.

The Monotony of Tinning.—The work of the tinman employed on the Abercarn pot appears to be very monotonous. Every two or three minutes he pulls out a batch of recently pickled plates, numbering from fifteen to fifty, from the trough of water near his pot, and puts them on a slab close at hand. He lifts up each sheet separately and pushes it into the tinning bath, which holds from two to four plates side by side, according to their size. This process is continued with

very little intermission throughout the eight-hour shift, except for a half-hour interval for food near the middle. In order to get a rough idea of the number and duration of the breaks from the monotonous tinning, the men were watched for a number of hours. Data relating to thirteen man-hours were obtained; and during this time the tinman got, on an average, 2.2 breaks per hour, lasting in the aggregate 4.8 minutes. During 1.0 break (lasting 1.3 minutes) the tinman was engaged in rectifying a plate which had gone astray either in the tinning bath or in the cleaning apparatus; during 0.6 break (lasting 1.6 minutes) he was stoking the furnace; and during 0.6 break (lasting 4.2 minutes) he had a rest, his place being taken temporarily by the helper. In addition to these breaks, the tinman occasionally pushed an aberrant plate straight as it passed through the bath, or ladled a little tin from one trough to another; but if any such process took more than 7 seconds, it was noted down and included in the foregoing estimates.

The operator of the Melingriffith machine has much more variety. Though he appears to be standing by idly watching his machine, he can never relax his attention and must always be on the alert, for owing to its size and complexity the machine may need attention in a number of ways and directions. A rough indication of the frequency and duration of the breaks from passive watching was obtained by keeping under observation six men for one or two hours each. On an average they got 18 breaks per hour, lasting 13 minutes in the aggregate. Of these breaks 11.0 (lasting 0.7 minute each) were spent on the hot gangway over the tin bath; 0.9 (lasting 2.0 minutes each) were spent in stoking, and 6.2 (lasting 0.5 minute each) were spent in other jobs not involving exposure to heat. In order to run a Melingriffith machine properly, the operator needs to possess considerably more intelligence and initiative than the tinman on the Abercarn pot. If he is quick, by immediate stoppage of the machine he can usually catch a plate when it is beginning to go astray during the pickling or washing stage, and can thereby prevent further mischief; or again, he can stop a tinned plate which has oil on it from passing to the cleaning rollers; or he can speedily rectify any plates which have gone astray in the dusting and cleaning.

IV. Lost Time

Certain information as to total lost time during two periods at three factories is available which is of interest, although the numbers concerned are small. (See Table 3.) During the first period the men were working at Abercarn pots and during the second at Melingriffith machines.

At Factory M the average time lost per week by thirty-six tinmen in the first period was 0.34 day. The ages of only seventeen of these men could be obtained in 1924, and the average lost time for them, *viz.*, 0.35 day, is practically identical with that of the whole group. Another group of six men, rather younger than the group of seventeen, experienced in this period slightly less lost time, *viz.*, 0.32 day; but these six men, when acting as operators in the second period, experienced lost time of only 0.04 day, which is eight times less.

Since these men were now seven years older, they might have been expected to experience more rather than less lost time. A further small group of three younger men, who had never acted as tinmen, in the second period experienced a much higher lost-time rate, *viz.*, 0.14 day; but this rate is still considerably lower than the rates experienced by either of the groups of tinmen.

At Factory A eleven tinmen experienced an average lost time of 0.39 day in the first period. A further group of eight men, rather younger, in this period experienced less lost time, *viz.*, 0.28 day. This group when acting as operators in the second period and when seven years older lost 0.11 day, or less than half their experience in the first period.

The suggestion might be made that the second period was for some unexplained reason more conducive to good

TABLE 3.—LOST TIME EXPERIENCED AT THREE FACTORIES BY TINMEN AND BY OPERATORS OF AUTOMATIC TINNING MACHINES

FACTORY	OCCUPATION	NUMBER OF MEN	PERIOD	TOTAL NUMBER OF WEEKS WORKED	TOTAL NUMBER OF DAYS LOST	AVERAGE DAYS LOST PER WEEK	AGES IN 1924		
							Youngest	Median	Oldest
M	Tinmen	36	Nov. 28, 1914 to Oct. 21, 1916	2,089	718	0.34	..	..	..
	Tinmen	17 of above	Same	1,042	360	0.35	35	46	59
	Tinmen	6	Same	416	132	0.32	33	43	48
	Operators		Nov. 26, 1921 to Nov. 24, 1923	609	25	0.04			
	Operators	3	Same	297	415	0.14	22	26	43
A	Tinmen	11	Nov. 28, 1914 to Oct. 21, 1916	1,034	399	0.39	35	43	52
	Tinmen	8	Same	752	210	0.28	33	35–38	55
	Operators		Nov. 26, 1921 to Nov. 24, 1923	824	104	0.11			
L	Tinmen	8	June 25, 1910 to June 29, 1912	824	43	0.05	40	48–49	52
	Operators		Nov. 26, 1921 to Nov. 24, 1923	613	29	0.05			
	Tinmen	11	Same	1,122	28	0.02	39	48	62

timekeeping. The records of factory L do not support this view. The interval between the two periods, eleven years, is greater in this instance. A group of eight men, while acting as tinmen in the first period and as operators in the second, experienced the same amount of lost time, 0.05 day; while a group of eleven tinmen, of about the same age, in the second period experienced an average of only 0.02 day. The lost-time rates at this factory are remarkably low. They are mainly of interest in showing that men as operators experienced no more lost time than they had done eleven years before as tinmen. At the factory in question certain factors exist which make for good timekeeping. The factory is not in an industrial environment, but is placed on a site open to a river and in a district rural in character. Another point is that practically the smallest units of tinning machines of the old (Abercarn type) system of tin-plate making exist here, resulting at once in less fatigue, but with a correspondingly less earning capacity. Hence the inducement to keep good time and the capacity to do so are both present.

The records for operators quoted above for the second period all refer to men at work at the new patent machines before they were fitted with hoods and ducts for carrying away the fumes which arise from the pots. Even so, the operators have been far less exposed to these fumes, to dust, and to heat than are tinmen. In the future, with the exhaust system in action, the exposure will be negligible. The preponderating advantage to the men has been freedom from rather monotonous physical labor, and the advantage gained with regard to lost time may probably be ascribed to this influence at least as much as to better atmospheric conditions with less exposure to heat, fumes, and dust, and to less physical effort.

V. Conclusions

An operator of a Melingriffith machine is exposed to (*a*) less radiant heat, (*b*) a lower air temperature, (*c*) a more rapid air current, and (*d*) less fumes and dust, than a tinman on an Abercarn pot. Moreover, his work calls for the expenditure of less physical energy and is much less monotonous. On the other hand, as the stokeholes are at present arranged, the stoking of the furnaces is considerably more arduous.

The total effect of these altered conditions results in less lost time. This may be taken as an index of better health and greater earning capacity.

Fourth International Medical Congress of Industrial Accidents and Diseases, Amsterdam, September, 1925

The British Committee of the above Congress has now been completed and is composed as follows:

Hon. President: The Minister Plenipotentiary of the Netherlands to the Court of St. James, Jhr. Mr. R. de Marees van Swinderen.

President: Sir Thomas Oliver.

Vice-President: Professor E. L. Collis.

Hon. Treasurer: Dr. C. S. Thomson.

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Dr. D. A. Coles, Sir William Collins, K.C.V.O., Professor J. Glaister, Sir K. W. Goadby, K.B.E., Sir Wm. Hale-White, K.B.E., Sir R. Jones, K.B.E., C. B., Dr. J. R. Kerr, C.B.E., Dr. A. Mercer, Dr. Howard Mummery, Dr. A. Scott, Dr. C. S. Thomson, Dr. Theodore Thompson, Dr. A. Trimble, Dr. H. M. Vernon, Dr. Thos. Watts, M. P., Dr. Prosser White.

The Congress will meet on Monday, September 7, and will continue until Saturday, September 12. An attractive program has been arranged. There will be two Plenary Sessions, one after the opening and the other toward the close of the Congress. The Sections will meet on the other days.

Men well known in the field of industrial diseases and accidents will read papers. Every effort is being made to make this Congress an international success. As it is the first Congress since the war, the British Executive Committee begs to express the hope that the British Section will play a useful and a leading part in the deliberations of the Congress.

Apart from the scientific proceedings of the Congress, there are other attractions which ought to appeal to English members. The following are some of the items expected:

A Reception by the County Council of Amsterdam.

A Reception by the Minister of Labor at the Hague.

A Trip to the harbors and the surroundings of Amsterdam.

A Ladies' Committee has been formed in Amsterdam to receive the ladies accompanying the members, and every effort is being made to make this part of the Congress a brilliant social success.

The cost of a ticket for each member will be £15; this includes admittance card to the Congress, return ticket to London (the return journey may be made at the member's own time within one month), room and breakfast in one of the leading hotels in Amsterdam, admittance to the Congress dinners, official receptions, etc.

Further information can be obtained from the Hon. Secretary, Dr. Herman S. N. Menko, 2 Grosvenor Gardens, Cricklewood, London, N. W. 2.

J. I. H.
Apr., 1925